Before the
Federal Communications Commission
Washington, D. C. 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

In the Matter of	)	
	)	
An Inquiry into the Commission's	)	
Policies and Rules Regarding	)	MM Docket No. 93 - 177
AM Radio Service Directional	)	
Antenna Performance Verification	)	

Comments of
Hatfield & Dawson Consulting Engineers, LLC

This response is organized in the same outline form as the NPRM:

I. Introduction

As one of the five engineering firms which jointly filed the Petition for Rulemaking (and the original request for a Notice of Inquiry) in the matter of Performance Verification for medium wave directional antennas, Hatfield & Dawson is delighted to see the Commission undertake long overdue reforms in the necessary processes.

II Computer Modeling versus Proof of Performance

The Commission's choice of a paragraph heading for this section is in itself a clear indication of the deep level of misunderstanding of the basic physical principals of electromagnetic field behavior at MW frequencies in a realistic environment. The Commission's NPRM failed to take into account the inadequacies of the present methods of antenna performance determination by measurement of magnetic field values, and ignored entirely the demonstrated record of the use of numerical analysis methods to determine array performance.

Together with a large number of other qualified consulting engineering practitioners and a substantial body of group owners of medium wave broadcast stations, we call on the Commission to issue a further NPRM to more clearly define the circumstances in which numerical analysis methods can be used to replace magnetic field intensity measurements for proof of performance verification. The Appendix to these Comments provides additional material pertinent to this request.

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III Directional Antenna Proofs of Performance

A. Full Proof of Performance

1. Number of Radials

The NPRM proposed a minimum of six, maximum of twelve radials, including one in the major lobe, and 5 others at pattern inflections, with no arc greater than 90 degrees between adjacent radials. Anyone who has ever implemented a directional antenna knows that maximum lobe performance is not difficult to achieve, and is easily verifiable with at most one or two spot measurements. Further, it is a market competitive requirement for responsible licensees. Therefore, it is not necessary that it be included in the proof of performance requirement, unless the antenna design includes radiating elements which are not simple vertical radiators.

Directional antenna patterns can be characterized by their performance over sectors of azimuth, as is specified in the GE-75 Agreement which governs medium wave broadcast operation outside the western hemisphere. A factor which the NPRM did not consider is a minimum distance between adjacent radials. In general, radials which are closer than 10 degrees do not provide useful data about pattern shape or size, and should therefore not be required.

In the case of arrays which produce symmetrical patterns, the number of radials should be reduced further, so that as few as three or four radials may be used for a simple array with only two inflections (one minimum and one maximum) which is symmetrical, especially if the array is linear as well as symmetrical. The pattern features and not the number of towers in the array should be used to determine the radial requirement and any monitor point requirements.

2. Number of Points per Radial, Length of Radials

While the Commission's suggested reduction in the number of measurement points required for each radial is a reasonable one, we do not believe that the distance specifications outlined in paragraph 15 of the NPRM should be absolute requirements. It would be more appropriate if these specifications could be characterized as appropriate for most normal circumstances. In many instances, accurate measurements of arrays can be made at distances closer than 10X the maximum array element spacing, especially if accurate predicted values are known from numerical analysis. In many other instances, sectors of a radial may simply be unuseable for measurement analysis purposes because of one or more of the factors which may make accurate magnetic field measurements impossible, such as terrain, conductivity changes, bodies of water, large corridors of power transmission lines, and the like. It is not uncommon to find that only the distant points on a radial are valid for determination of the inverse distance field. Each case is unique, and sufficient flexibility must be provided to allow accurate analysis. The statement in footnote 12 does not meet these requirements.

We support the use of a standard format for the submission of measurement data, so long as the format can be generated with and read by common spread sheet programs such as Quattro and Excel. The format should not be a "pdf" file such as those employed by the Commission for electronic forms. Data produced by our office has been submitted in spread sheet format for many years, and this has reduced errors and made analysis simpler and less ambiguous. The Commission should not, however, discourage submission of field intensity data in "groundwave graph" format when appropriate, since graphical analysis is necessary for proper characterization of data in difficult situations. The tabular spread sheet format should provide data fields for distance and field intensity, time and date of measurement, and for any necessary mathematical analysis. Points need not be numbered, as the distance is unique to each point on a radial.

B. Partial Proof of Performance

If the requirements for a full proof of performance can be sufficiently simplified, there is no longer a real requirement for a partial proof of performance.

1. Number of Points Required
If a partial proof of performance is considered to be useful, it should be scaled back to be no more than 33% of the measurement requirements of a full proof of performance, or 5 points per radial in most cases.

2. When Required
We agree with the proposal to eliminate the requirement when sample system components are changed, unless it is necessary to allow readjustment and specification of revised parameters. We agree that installation of new components on a tower (usually antennas of one sort or another) should trigger a requirement for a partial proof of performance, but we do not agree that replacement of lighting components or of guy wires or other existing components should trigger such a requirement.

C. Monitoring Points

We do not agree that GPS or even differential GPS coordinates are a completely satisfactory method for description of measurement points, but they are better than no description at all. The Commission has removed monitor point descriptions from licenses, making it difficult to find the descriptions in station files and even in the Commission's files. We feel that a physical description of the monitor points (distance and bearing, description of point where actual measurement was made, and any appropriate comments about the measurement technique employed at that point) need to be incorporated in the station license. Footnote 20 contains the language "would still be required" but that's not much help in the instances where the original 302 filing can't be located.

As noted in II.A.1, the number of monitor points required should be determined by the inflections of the pattern and not by the number of towers in the array.

IV AM Station Equipment and Measurements

A. Base Current Ammeters

Base current ammeters are a relic of the shortcomings of early sample systems. Both thermocouple and toroidal transformer ammeters are often inaccurate due to the effects of environment. In antenna systems with tall towers, whose antenna monitor samples are taken at an elevated location on the array elements, base current meters may produce very misleading and inaccurate readings because they meter the quadrature current flowing in the tower base vicinity as well as the excitation current. They are an anachronism which should have been eliminated years ago.

B. Antenna Monitors

We agree with the proposal of footnote 27, but we do not understand the concern by manufacturers about any limiting effects of the requirements of §73.53. These are essential minimum requirements for such monitors.

C. Impedance Measurements Across a Range of Frequencies

The requirement for measurements over a sweep of frequencies is a relic of the limitations of impedance measurement equipment configurations. The use of modern synthesized signal generators and detectors moots the requirement that an impedance sweep be made to allow ambiguities in the measured data to be resolved.

V. Critical Arrays

A. Antenna Monitors for Critical Arrays

If critical arrays are still identified, the proposal to eliminate the special antenna monitor requirements is very appropriate. All currently manufactured models of type-approved antenna monitors have been employed for critical array use on a waiver basis for at least a decade or more.

B. Designation of Critical Arrays

The critical array designation should be eliminated.

Indeed, one of the underlying purposes of the Commission's adoption of the "Standard Pattern" concept was to eliminate arguments about array stability from the allocation process. The selection of a scalar multiplier was primarily as a means of accounting for differences in basic array efficiency. The quadrature multiplier as a percentage of RSS resulted directly from Harry Fine's analysis in T.R.R 1.2.6 Report *"Physical Limitations for Directional Antenna Systems in the Standard Broadcast Band,"* issued in 1952. Throughout the period before adoption of the standard pattern, applications proposing arrays with high suppression (and sometimes with equally unrealistic Maximum Expected Operating Values or "MEOV's") were often challenged on stability grounds.

The Commission could have adopted a method of determination of the standard pattern based on parameter variation. At least one commenter in the rulemaking (Docket 16222) made such a suggestion. However, upon review of the statistical nature of the underlying allocation process and of the equally statistical nature of the performance of directional antennas, the Commission chose a straightforward formula using a quadrature component with a relatively high minimum in the cases of arrays with low RSS values, and 2.5% of the RSS in cases where that percentage exceeded the minimum. Fine's analysis in T.R.R. 1.2.6 and the subsequent T.R.R.1.2.7 (Damelin & Fine, 1957) demonstrated clearly the relationship between RSS and array performance.

Adoption of the Standard Pattern rule should have been the end of the stability challenge problem. Unfortunately the use of stability challenges as a harassment tool continued, and applicants found it expedient to agree to less than normal parameter variation limits as a method of obtaining grants of their applications.

The use of the arbitrary challenge as a method of determining "critical array" requirements is unfair and discriminatory. The adoption of any standard test by the Commission is unreasonable and unnecessary and amounts to a modification of the standard pattern rule itself. And, as proposed by the Commission, it would be just as unfair and discriminatory as the present situation, since it would be applied only to applications and not to existing facilities.

November 9, 1999

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/s/ Benj. F. Dawson III, P.E.
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APPENDIX

1. THE INADEQUACY OF MAGNETIC FIELD MEASUREMENTS FOR ANTENNA PERFORMANCE VERIFICATION

Although we no longer see them frequently written as explicit assumptions as we formerly did, the basic premises about medium frequency vertical element radiators for FCC allotment purposes include assumptions of sinusoidal current distribution and a uniform perfectly conducting plane earth in the antenna or antenna array vicinity. These are, of course, simplifying assumptions. Published papers and other works by Rackley, Hatfield, Lahm, and by a group of Canadian academics have described the methods, using numerical analysis techniques, for the calculation of actual current distribution. These methods have been extensively compared with measured data, both as verification of the methods and as a means of predicting far field radiation, and have proven to be extremely accurate. Careful modeling, especially when combined with some empirical data, has allowed very accurate impedance predictions as well. The results of these efforts have allowed large numbers of MF antenna arrays to be placed into operation without any necessity for "empirical adjustment" procedures.

In the instances where these antenna arrays were located within the jurisdiction of the FCC, their performance has been "confirmed" by field strength measurement.

It is this "confirmation" part of the process that is under consideration. The problem is that the measurement program traditionally used does not work well with anything except very uniform smooth high conductivity terrain. The effects of realistic terrain cause the data to possess location variability that is not included in the simplistic theoretical model. This results in the analysis and presentation of magnetic field measurements in a manner that is so simplistic that it is thoroughly ambiguous in a very large percentage of instances.

A careful review of Norton's 1941 paper "The calculation of ground-wave field intensity over a finitely conducting spherical earth" and of recent work based on Norton's theoretical methods, such as the papers of Eckert and DiMinco, discloses the simplifying assumptions. These simplifying assumptions were vital to the task, which was primarily devoted to the prediction of propagation. Effects of changes in conductivity, most diffraction effects, and discontinuities in dielectric constant are not considered. Review of the literature and the complex mathematical analysis necessary to describe even the simplified circumstances treated by these authors (and many others, including King, Wait, Burrows, and Bremmer) makes it obvious why these simplifications were used. Even the simple case of mixed conductivity with no diffraction and uniform dielectric constant is difficult, and the Millington and Kirke methods for resolution of these situations both fail to correctly describe many real circumstances.

Analysis of measured data is an even more intransigent task. Causebrook, in three papers in the late 1970's, described the enormous range of variability - in some cases values exceeding 20 dB -

of the relationship between electric and magnetic field of MF groundwave measured signals in even moderately "built up" semi-urban terrain. Anderson, in two papers in the late 1980's, showed that measured magnetic fields exhibit substantial location variability that could not be resolved by any other than statistical methods, but his treatment does not discuss the sources of this variability in other than very general terms.

Finally, it is well known that finite antennas, such as the ubiquitous monopole and arrays of monopoles, exhibit proximity effect as a result of their finite dimensions. What is less well known, although easily shown by both measurement and numerical analysis, is that it is common for such antennas to exhibit "near-field" effects, often to distances of many wavelengths, where the relationship between E and H fields is far from the free space condition. And this type of near–field effect is not uncommon for re-radiators as well, especially for re-radiators which are loops rather than vertical scatterers.

The result of all these factors is that magnetic field measurements are an unreliable method for the determination of antenna performance in realistic environments. The ambiguous nature of the measured data results in a process which relies upon oversimplification of analysis. The process can result in large errors, or, equally large subterfuges. Attempts to "automate" or somehow produce an unambiguous analysis process have not been satisfactory. Any attempt to perform meaningful statistical analysis on the relatively small number of data points on one measurement radial from an MF antenna is doomed by the large number of variables that have influenced the data. Even if all other factors were equal, the normal graphical method of analysis of unambiguous data is still an attempt to solve for two unknowns with only a single equation.

There are at least dozen factors which can produce magnetic field measurements that are not meaningful. They include:

1. Surface layer impedance/dielectric discontinuities due to vegetation,
2. Conductivity changes due to soil or other surface geology changes,
3. Dielectric constant changes due to soil or surface geology changes,
4. Conductivity and dielectric constant changes due to bodies of water,
5. Diffraction effects due to rugose topography
6. Diffraction due to abrupt changes in conductivity or dielectric constant or both
7. Electric field distortion due to electrically small vertical scatters
8. Magnetic field distortion due to finite sized loops of conducting material
9. Absorption by poor conductor structures (wet concrete)
10. Quasi-transmission line or ducting effects by urban streets with parallel rows of structures
11. Reflection or multipath effects from slopes of good conductivity soil
12. Quasi-free space propagation in curving sloped terrain
13. Near-field effects from arrays of radiators
14. Localized near field effects from re-radiators

The resulting effects on magnetic field measurements mean that, in the absence of a priori assumptions about the behavior of the antenna under study, the analysis of measured data is subject to errors of as much as 6 to as much as 10 dB, and cannot be more accurate than about 2 dB. The use of omni-directional measurements for calibration of the process improves this somewhat, but does not come close to resolving the ambiguities. When combined with ambiguities of location (which cannot be entirely overcome by GPS equipment) and the lack of judgement and/or knowledge of many of those who make the measurements, the result is that, like many other semi-scientific processes, the only real information obtained from a magnetic field strength measurement is that the value is the number that was transcribed by the measurement taker at that particular time and location, and little else.

In summary, the reason that the process for performance verification for MF antenna systems needs to be changed is that the present method is not sufficiently accurate to produce the necessary and appropriate results. It was adopted when it was the best method but it no longer is.

In contrast, in every instance that we are aware of where a suitably constructed and non-ambiguous antenna monitoring system was used, the use of numerical analysis techniques to determine array adjustment has resulted in far field performance that was correct and within the FCC's requirements. The same cannot be said of many of the arrays we have adjusted or rebuilt which had originally been adjusted and "proved" by field measurement techniques. An alarmingly large percentage of arrays are, in fact, not in proper adjustment even when they are within the limits of the licensed antenna monitor and monitor point values, and often this fact can be determined from the previous measurement data itself.

The time has come to eliminate total reliance on field measurements for antenna performance verification.

2. THE RELATIONSHIP BETWEEN PERFORMANCE VERIFICATION BY MAGNETIC FIELD MEASUREMENTS AND NUMERICAL ANALYSIS MODELS

Over 10 years ago the record of success in adjustment of MW antennas to moment method generated parameters and their verification by field measurements was documented in the paper "Relative Tower Currents and Fields in an AM Directional Array," by J. B. Hatfield, *IEEE Transactions on Broadcasting,* vol.35, No. 2, p. 176-184, June 1989.[1] The section "Measured Results" is specifically pertinent. In every instance known to us where the antenna monitor and sample system were adequate, moment method generated antenna monitor values have yielded correct far field pattern characteristics.

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[1]This paper is not included with these comments only because it is copyrighted by IEEE.

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